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H3A H4P
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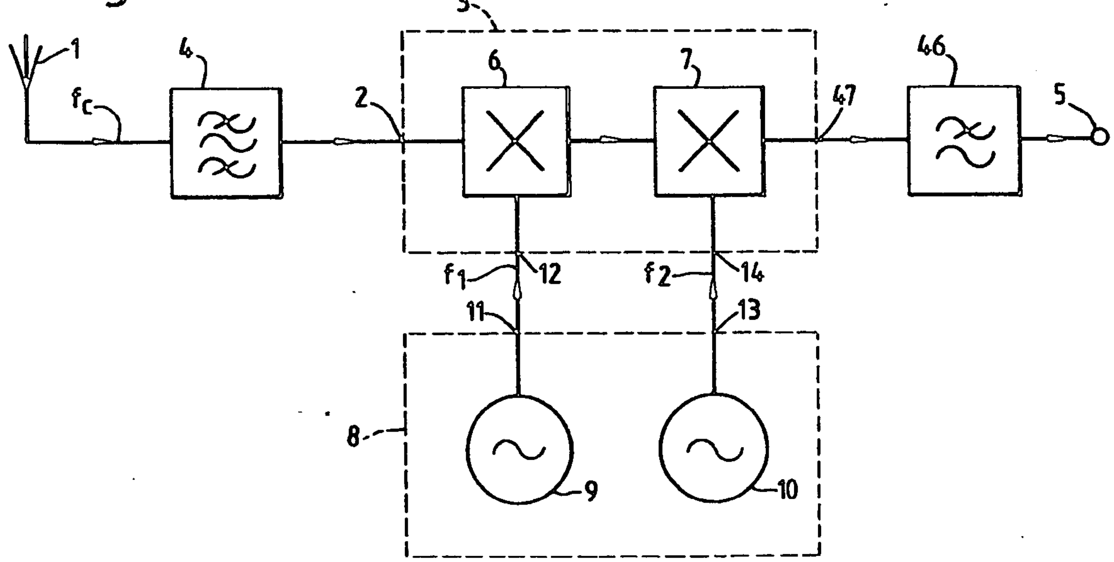
(54) Superheterodyne radio receiver

(57) A modulated input signal of nominal carrier frequency f_c received on an aerial 1 is converted to base-band at an output terminal 5 by a mixer 3 also fed from a local oscillator 8. If the mixer consisted of a single mixer stage the local oscillator output frequency would have to be f_c, with the result that leakage of this signal to the aerial 1 would result in this being treated as part of the input signal and hence in an unwanted and unpredictable d.c. component at the output terminal 5. Accordingly the conversion is effected by two mixer stages 6, 7 in cascade, the local oscillator frequencies f_1 and f_2 fed to these two stages both lying outside the pass-band of an input filter 4 and satisfying the relation $|f_c \pm f_1| = f_2 \pm$ delta, where delta lies within the frequency range from zero to half the receiver reception bandwidth as defined by a base-band pass filter 46 included between the mixer output 47 and the output terminal 5. A transistor circuit (Fig. 2) is described for the mixers 6 and 7. The received signal may be an FSK signal. In a modification (Fig. 3) a third mixer (7A) is fed with the output from mixer 6 and with the output of the oscillator 10 via a 90° phase shifter (42).

Fig.1.



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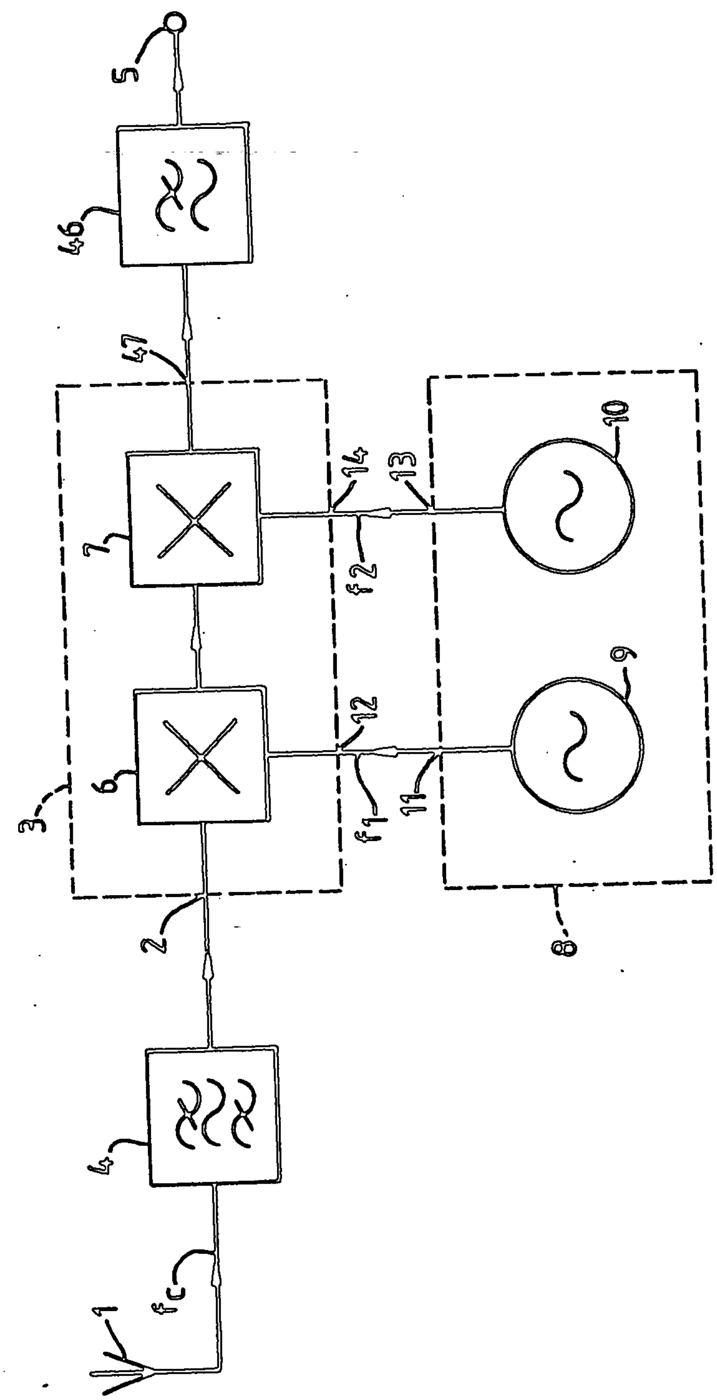

Fig.1.

Fig.2.

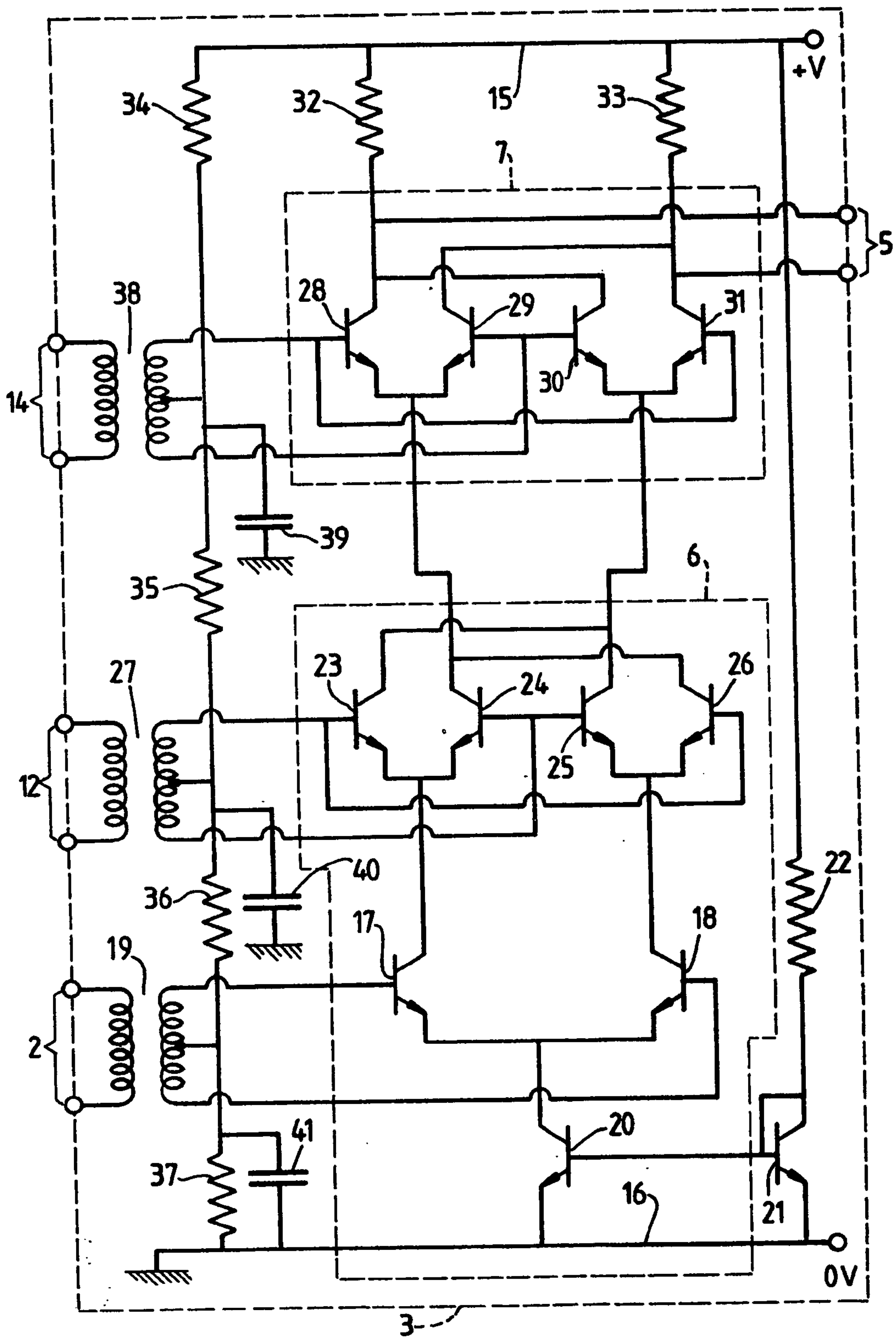

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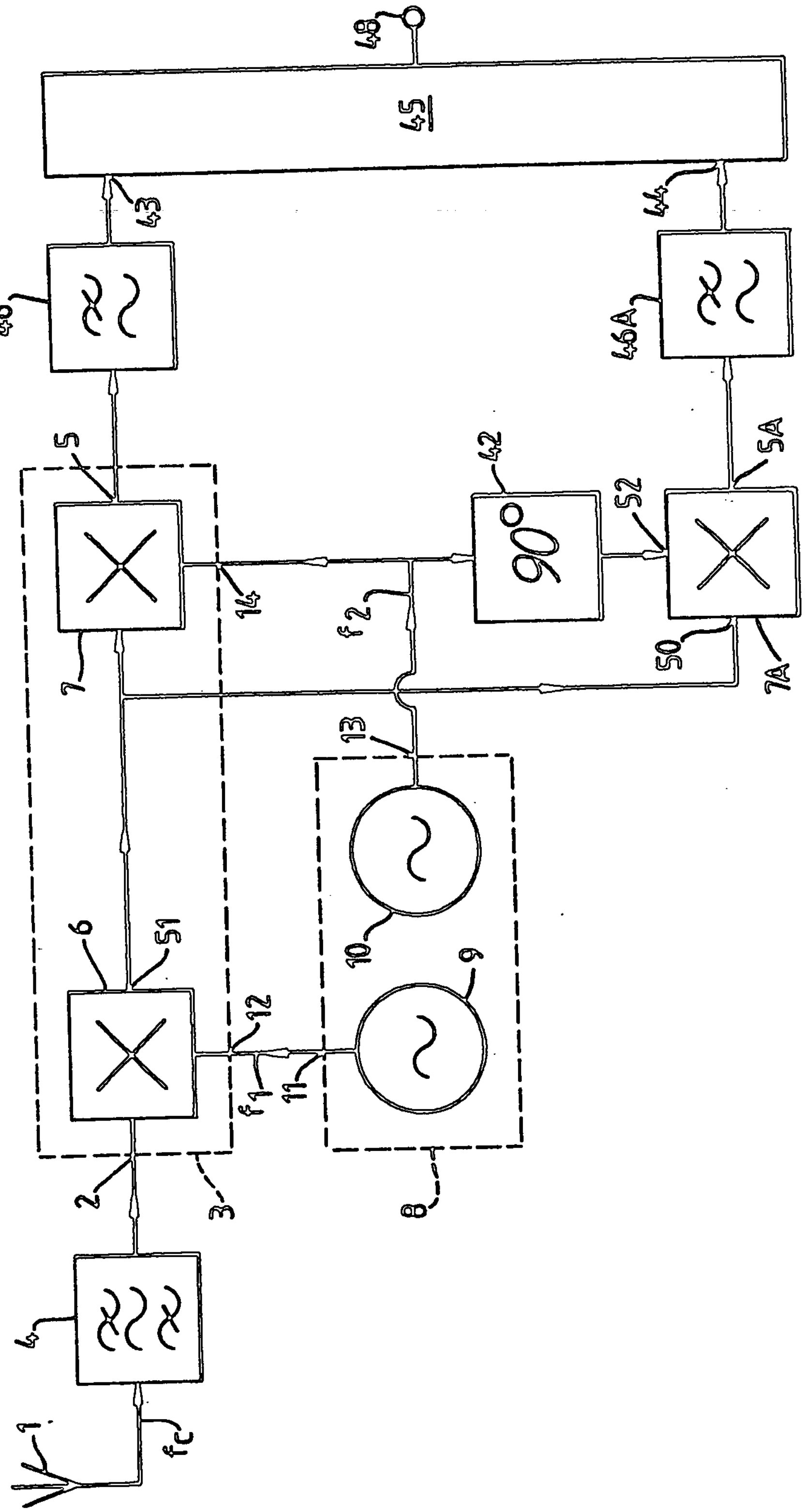
Fig.3.



SPECIFICATION
Superheterodyne radio receiver

This invention relates to a superheterodyne radio receiver comprising a pass filter for a frequency range containing a frequency f_c, which filter has an input for a received signal and an output, local oscillator circuit means for producing a signal of frequency f_1 at an output thereof, a mixer circuit having a first input to which the filter output is coupled, a second input to which the said output of the local oscillator circuit means is coupled, and an output, for translating a modulated signal of nominal carrier frequency f_c applied to said first input to base-band, and a base-band pass filter to which the output of the mixer circuit is coupled.

A known such receiver is described, for example, in an article by I. A. W. Vance entitled "An integrated circuit VHF radio receiver" in Proc. IERE Conf. Land Mobile Radio, No. 44, pages 193—204, September 1979, and is particularly suitable for construction in integrated circuit form. In the known receiver $f_1 = f_c$, so that the mixing of a received modulated signal of nominal carrier frequency f_c with the local oscillator output signal results directly in a difference frequency component which is the desired base-band-translated modulated signal.

A problem with the known receiver is that it is well-nigh impossible to prevent leakage of a portion of the local oscillator signal of frequency $f_1 = f_c$ to the input of the pass filter and hence being treated by the mixer circuit as a component of the received signal, resulting in a spurious d.c. component in the mixer output signal. If the leakage were constant such a d.c. component could, for example, be removed by applying an equal but oppositely-directed d.c. offset to the mixer output signal. However, in practice the leakage is found to vary with ambient conditions and hence to be unpredictable so such an expedient does not give satisfactory results. It is accordingly an object of the invention to provide an alternative to the known receiver in which the aforesaid problem does not arise or at least arises to a lesser extent.

The invention provides a superheterodyne radio receiver comprising a pass filter for a frequency range containing a frequency f_c, which filter has an input for a received signal and an output, local oscillator circuit means for producing a signal of frequency f_1 at an output thereof, a mixer circuit having a first input to which the filter output is coupled, a second input to which said output of the local oscillator circuit means is coupled, and an output, for translating a modulated signal of nominal carrier frequency f_c applied to said first input to base-band, and a base-band pass filter to which the output of the mixer circuit is coupled, characterised in that the local oscillator circuit means has a further output for a signal of frequency f_2 and in that the mixer circuit has a third input to which said further output is coupled, the frequencies f_1 and f_2 both lying outside said range and satisfying the condition

$$|f_c \pm f_1| = f_2 \pm \text{delta},$$

where delta lies within the frequency range from zero to half the receiver reception bandwidth as defined by the base-band pass filter.

It has now been recognised that effectively converting the received signal to base-band in two steps means that neither of the local oscillator frequencies f_1 and f_2 has any longer to be equal to the nominal carrier frequency f_c, making it possible for both to be chosen to lie outside the pass frequency range of the first filter. (They are preferably chosen so that also their harmonics lie outside said pass frequency range). When they are so chosen then, if leakage of the corresponding signals to the input for the received signal should occur, these signals will be attenuated by the filter and thus be prevented from reaching the mixer circuit by this route or, if they should so reach the mixer circuit, be considerably attenuated in the process.

It should be noted that an article by W. G. M. Straver, E. H. Nordholt and H. K. Nauta entitled "A Synchronous phase-lock loop detector for integrated A.M. radio" in IEEE J. of SS Circuits, Vol. SC—19, No. 4, August 1984 discloses a superheterodyne radio receiver which is provided with a pair of quadrature synchronous detectors for the IF signal, these detectors being implemented as balanced current switches. However, in this known receiver it appears that the receiver selectivity is completely realised in a concentrated ceramic IF filter.

The mixer circuit in a receiver constructed in accordance with the present invention may comprise first and second mixer stages with an output of the first mixer stage coupled to a first input of the second mixer stage, first and second inputs of the first mixer stage and a second input of the second mixer stage constituting individual ones of the said first, second and third inputs of the mixer circuit. If this is the case then, because in many circumstances it will not be necessary to provide, for example, filtering of the output signal of the first mixer stage prior to its application to the second mixer stage, the output of the first mixer stage may be directly connected to the first input of the second mixer stage. This can result in a comparatively simple mixer circuit which is highly suitable for construction in integrated circuit form.

If a received signal is of the non-symmetrical double-sideband type then, as is known, provision of two parallel signal channels operating in phase quadrature in a receiver therefor enables a distinction to be made between energy in the upper sideband and energy in the lower sideband, as is normally required. Such parallel signal channels can conveniently be created in a receiver constructed in accordance with the present invention in which the mixer circuit comprises first and second mixer stages in cascade as referred to above in which the first and second inputs of the first mixer stage and the second input of the second mixer stage constitute the first, second and third inputs of the mixer circuit respectively and in which the local

oscillator circuit means comprises a local oscillator an output of which is coupled to the said further output of the local oscillator circuit means by including in the receiver a third mixer stage to a first input of which is coupled the output of the first mixer stage and to a second input of which is coupled the output of the local oscillator for supplying a signal of frequency f_2 to said second input, a further base-band pass filter to which the output of the third mixer stage is coupled, and means for creating a 90 degree phase difference between the signals supplied to the second input of the second mixer stage and the second input of the third mixer stage. Thus the splitting into the two channels can be arranged to occur after the output of the first mixer stage, enabling the second and third mixer stages to operate on signals of fixed frequency (if the receiver overall is required to be tunable over a range of received frequencies) and hence facilitating the creation of the 90 degree phase difference.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a block diagram of a first embodiment,

Figure 2 is a detailed circuit diagram of a possible construction for part of the embodiment of Figure 1, and

Figure 3 is a block diagram of a second embodiment.

In Figure 1 a superheterodyne radio receiver has an input 1 for a received signal, which input is in the form of an aerial and is coupled to a first input 2 of a mixer circuit 3 via a band-pass filter 4. The pass-band of filter 4 contains a frequency f_c and the mixer circuit 3 translates received signals of nominal carrier frequency f_c applied to the aerial 1 and hence transmitted by filter 4 to the mixer input 2, to base-band. The signals so translated appear at an output 47 of the mixer circuit whence they are applied to an output 5 of the receiver via a low-pass base-band filter 46 and possibly also a d.c. block capacitor (not shown). If such a d.c. block capacitor is provided the overall frequency characteristic from mixer circuit output 47 to output 5 will, of course, be band-pass. The mixer circuit 3 comprises first and second mixer stages 6 and 7 respectively in cascade, which stages are supplied with local oscillator signals of frequencies f_1 and f_2 respectively from local oscillator circuit means 8. To this end the local oscillator circuit means 8 comprises first and second local oscillators 9 and 10 respectively, which oscillate at the frequencies f_1 and f_2 respectively. The output signal of oscillator 9 is fed to the mixer stage 6 via an output 11 of circuit means 8 and a first input 12 of the mixer circuit 3. Similarly the output signal of oscillator 10 is fed to the mixer stage 7 via a further output 13 of circuit means 8 and a second input 14 of mixer circuit 3. In operation a modulated signal of nominal carrier frequency f_c, for example a single-sideband signal (possibly with suppressed carrier), which is received on aerial 1 is transmitted to the input 2 of mixer circuit 3 via filter 4, is translated to an intermediate nominal carrier frequency $f_c - f_1$ by mixer stage 6 and this intermediate frequency is then translated to a nominal carrier frequency $(f_c - f_1) - f_2$ by mixer stage 7. The output frequencies f_1 and f_2 of the (non-coherent) oscillators 9 and 10 are chosen to satisfy the relationship

$$|f_c - f_1| = f_2,$$

so that the nominal carrier frequency at the output of mixer 7 and hence at the terminal 5 is zero, i.e. the input signal at aerial 1 is translated overall by mixer circuit 3 to base-band. Both the frequency f_1 and the frequency f_2 are chosen to lie outside the pass-band of the filter 4 so that any part of the output signals of the oscillators 9 and 10 which leaks to the aerial 1 is prevented by filter 4 from reaching the input 2 of mixer circuit 3, or is at least attenuated strongly before doing so, so that it is not treated by mixer circuit 3 as constituting a significant part of the received signal (which would otherwise result in a significant spurious d.c. component at the output 5).

Although it has been assumed that the frequency f_1 is lower than the frequency f_c it will be evident that this is not necessarily the case, it merely being necessary that the relationship between f_c, f_1 and f_2 is such that input signals of nominal carrier frequency f_c are translated overall by mixer circuit 3 to base-band. Moreover the frequency f_2 may as an alternative be chosen equal to $f_c + f_1$ (mixers in general producing output signals having frequencies equal to both the sum of and the difference between the frequencies of their input signals).

If the receiver is intended for reception of signals, for example frequency-shift-keyed signals, the modulation characteristics of which satisfy certain criteria, it may, as is known, be of the so-called "offset" type, in which a nominal input carrier frequency f_c is translated by mixer circuit 3 to a value other than zero, which value, however, still does not exceed the upper cut-off frequency of the base-band filter 46. In such a case the relationship

$$|f_c \pm f_1| = f_2$$

will no longer be satisfied exactly, it being relaxed to

$$|f_c \pm f_1| = f_2 \pm \text{delta},$$

where delta lies within the frequency range from zero to half the receiver reception bandwidth as defined by filter 46.

Although the local oscillator circuit means 8 has been described as comprising two separate oscillators 9 and 10 it will be evident that it may in fact comprise a single oscillator the output of which is coupled to the outputs 11 and 13 via respective frequency dividers which produce respective sub-harmonics of the oscillator output signal or respective filters which select respective harmonics of the oscillator output signal. If it were not for the fact that it is highly desirable that the frequencies f_1 and f_2 are not harmonically related to the frequency f_c the single oscillator could even feed both the outputs 11 and 13 directly, i.e. the outputs 11 and 13

could even be combined.

A pass filter which includes within its pass frequency range that one of the frequencies $f_c + f_1$ and $f_c - f_1$ which corresponds substantially to f_2, may be included between the output of mixer stage 6 and the input of mixer stage 7, as may amplification stages, if desired. However, in many cases such a filter will not be necessary because it can be arranged that filter 4 removes any signals in the region around f_2 which might otherwise reach the output of mixer 6 via aerial 1 in an unbalanced configuration and get mixed to base-band. If such a pass-filter is not provided it will be appreciated that the functions of the inputs 2, 12 and 14 of mixer circuit 3 are then completely interchangeable. Thus, for example, the output 13 of local oscillator circuit means 8 may then be connected to input 2 and the output of filter 4 be connected to input 14.

If desired the aerial 1 may form at least part of the band-pass filter 4. Thus, for example, the inductive part of filter 4 may be constituted by a relatively large loop of conductive material containing one or more turns, the two ends of the conductor being connected in parallel with a tuning capacitor so that the resulting resonant circuit resonates at substantially f_c and also being connected to the input 2 of mixer circuit 3. The loop will then form the input for the received signal.

Figure 2 is a detailed circuit diagram of a possible construction for the mixer circuit 3 of Figure 1. The construction shown in Figure 2 comprises, in effect, two double-balanced mixers 6 and 7 connected in series between a pair of d.c. power supply conductors 15 and 16. Mixer 6 comprises a first pair of emitter-coupled switching transistors 17 and 18 the bases of which are fed in antiphase from the input 2 via a transformer 19. The emitters of the transistors 17 and 18 are fed from the collector of a current-source transistor 20 which constitutes the output of a current mirror, its base being connected to the base of a diode-connected transistor 21 which is fed from the positive power supply line 15 via a resistor 22. The collectors of the transistors 17 and 18 are connected to the commoned emitters of a second pair of transistors 23, 24 and to the commoned emitters of a third pair of transistors 25, 26 respectively. The bases of the transistors 23 and 24 are fed in antiphase from the input 12 via a transformer 27, as are the emitters of the transistors 25 and 26. Mixer 7 comprises a fourth pair of transistors 28, 29 the interconnected emitters of which are fed from the interconnected collectors of the transistors 24 and 26, and a fifth pair of transistors 30, 31 the interconnected emitters of which are fed from the interconnected collectors of the transistors 23 and 25. The interconnected collectors of the transistors 28 and 30 are fed via a load resistor 32 from the supply line 15 and are also connected to one terminal of the (balanced) output 5. Similarly, the interconnected collectors of the transistors 29 and 31 are fed via a load resistor 33 from the supply line 15 and are also connected to the other terminal of the output 5. The bases of the transistors 28 and 29 are fed in antiphase from the input 14 via a transformer 38, as are the bases of the transistors 30 and 31. Suitable d.c. bias potentials are supplied to the bases of the various transistors by means of a potential divider comprising resistors 34, 35, 36 and 37 connected in series between the power supply lines 15 and 16, the junction of resistors 34 and 35 being connected to a centre tap on the secondary winding of transformer 38 and to a decoupling capacitor 39, the junction of resistors 35 and 36 being connected to a centre tap on the secondary winding of transformer 27 and to a decoupling capacitor 40, and the junction of resistors 36 and 37 being connected to a centre tap on the secondary winding of transformer 19 and to a decoupling capacitor 41. The transistors of Figure 2 together with their interconnections are preferably formed as a single integrated circuit on the same chip.

If the received signal applied to the aerial 1 of Figure 1 is, for example, an FSK (frequency shift keyed) signal the frequency of which switches between frequencies $f_c + f_d$ and $f_c - f_d$, the receiver of Figure 1 will not distinguish between input energy in the upper sideband and input energy in the lower sideband, as is normally required. As is known, for example from the publication referred to in the preamble, a distinction can be made with such signals by employing two parallel signal channels in the receiver, and combining the signals appearing at the outputs of the two channels, it being arranged that the signals passing through the two channels have a quadrature phase relationship with each other. Such channels are normally provided by connecting the output of the input filter (4 in Figure 1) to the inputs of two mixers, the other input of one of these mixers being supplied directly with the output signal of a local oscillator and the other input of the other mixer being supplied with this output signal via a 90° phase-shifter. If the receiver is tunable, i.e. if both the centre frequency of the pass-band of the input filter and the frequency of the local oscillator output signal are made variable, it can be difficult to obtain the required 90° phase shift accurately for all the possible values of the local oscillator output frequency. An extended version of the receiver of Figure 1 can provide a solution to this problem. A block diagram of such an extended version is shown in Figure 3 in which components having counterparts in Figure 1 have been given the same reference numerals.

The additional components of the receiver of Figure 3 as compared with those of Figure 1 are basically a third mixer stage 7A and a 90° phase-shifter 42, the outputs 5 and 5A of the mixer stages 7 and 7A respectively being connected to respective inputs 43 and 44 of a decoder 45 via low-pass base-band filters 46 and 46A respectively. Decoder 45 has an output 48. One input 50 of mixer stage 7A is connected to the output 51 of mixer stage 6 and the other input 52 thereof is fed from the output 13 of local oscillator circuit means 8 via the 90 degree phase-shifter 42. Thus the mixer stage 6 is common to the two channels feeding the inputs 43 and 44 respectively of decoder 45 and the quadrature relationship between the two channels is obtained by means of the phase-shifter 42. If tuning is

required in the receiver of Figure 3 this can be achieved by varying the output frequency of oscillator 9 (and the centre-frequency of the pass band of filter 4), the output frequency of oscillator 10, and hence also the frequency fed to phase shifter 42, being maintained constant. If the construction of Figure 2 is employed for the mixer circuit 3 the mixer stage 7A can be obtained in a simple manner by duplicating the transistor pairs 28, 29 and 30, 31 together with their load resistors and their base input circuits, preferably on the same semiconductor chip on which is formed the construction of Figure 2.

Similarly to Figure 1, if there is no pass filter in the output of mixer stage 6, the points to which the outputs 11 and 13 of local oscillator circuit means 8 and the output of pass-filter 4 in Figure 3 are connected are interchangeable, although it is preferred not to connect filter 4 to the junction point of input 14 and phase-shifter 42, because it will then be more difficult to provide phase-shifter 42 with the characteristic then required.

It is not essential to construct the filters 4 of Figures 1 and 3 as band-pass filters. In some cases constructing them as high-pass or low-pass filters may provide satisfactory results, provided always that the frequencies f_1 and f_2 both lie outside the pass frequency range of the filter.

CLAIMS

1. A superheterodyne radio receiver comprising a first pass filter for a frequency range containing a frequency f_c, which filter has an input for a received signal and an output, local oscillator circuit means for producing a signal of frequency f_1 at an output thereof, a mixer circuit having a first input to which the filter output is coupled, a second input to which said output of the local oscillator circuit means is coupled, and an output, for translating a modulated signal of nominal carrier frequency f_c applied to said first input to base-band, and a base-band pass filter to which the output of the mixer circuit is coupled, characterised in that the local oscillator circuit means has a further output for a signal of frequency f_2 and in that the mixer circuit has a third input to which said further output is coupled, the frequencies f_1 and f_2 both lying outside said range and satisfying the condition

$$|f_c + f_1| = f_2 \pm \text{delta},$$

where delta lies within the frequency range from zero to half the receiver reception bandwidth as defined by the base-band pass filter.

2. A receiver as claimed in Claim 1, characterised in that the mixer circuit comprises first and second mixer stages with an output of the first mixer stage coupled to a first input of the second mixer stage, first and second inputs of the first mixer stage and a second input of the second mixer stage constituting individual ones of the said first, second and third inputs of the mixer circuit.

3. A receiver as claimed in Claim 1 or Claim 2, characterised in that the output of the first mixer stage is directly connected to the first input of the second mixer stage.

4. A receiver as claimed in any preceding Claim, characterised in that the local oscillator circuit means comprises a single oscillator the output of which is coupled to both outputs of said local oscillator circuit means.

5. A receiver as claimed in Claim 2, or in Claim 3 when appended to Claim 2, wherein the first and second inputs of the first mixer stage and the second input of the second mixer stage constitute the first, second and third inputs of the mixer circuit respectively, wherein the local oscillator circuit means comprises a local oscillator an output of which is coupled to said further output, wherein the receiver includes a third mixer stage to a first input of which is coupled the output of the first mixer stage and to a second input of which is coupled the output of the local oscillator for supplying a signal of frequency f_2 to said second input, and a further base-band pass filter to which the output of the third mixer stage is coupled, and wherein means are provided for creating a 90° phase difference between the signals supplied to the second input of the second mixer stage and the second input of the third mixer stage.

6. A superheterodyne radio receiver substantially as described herein with reference to Figure 1, Figures 1 and 2 or Figure 3 of the drawings.

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